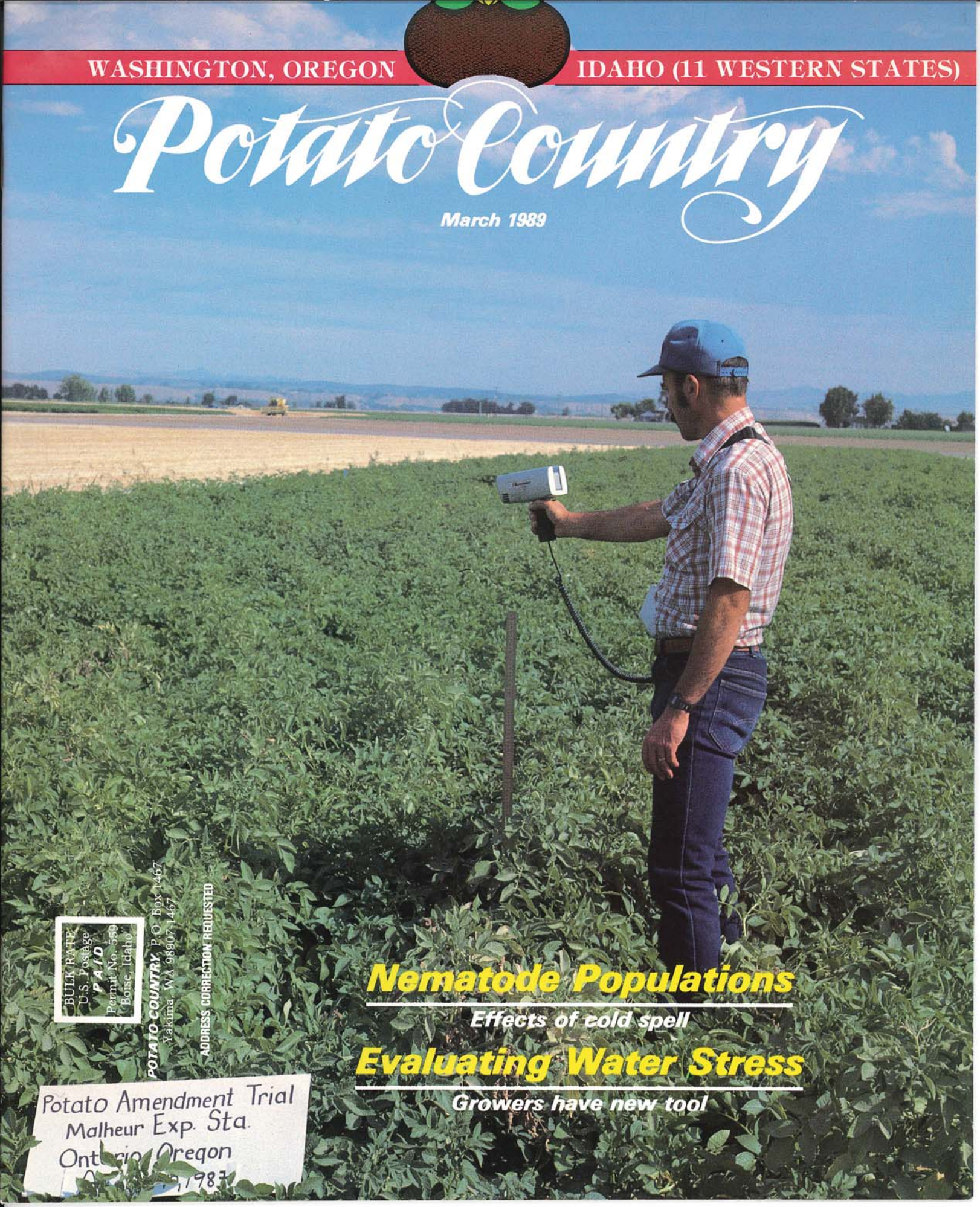
WASHINGTON, OREGON IDAHO (11 WESTERN STATES)

Potato Country

March 1989



Nematode Populations

Effects of cold spell

Evaluating Water Stress

Growers have new tool

BULK RATE
U.S. Postage
PAID
Permit No. 550
Boise, Idaho

POTATO COUNTRY, P.O. Box 1467
Yakima, WA 98907-1467

ADDRESS CORRECTION REQUESTED

Potato Amendment Trial
Malheur Exp. Sta.
Ontario, Oregon
1987

Advances in Evaluating Stress

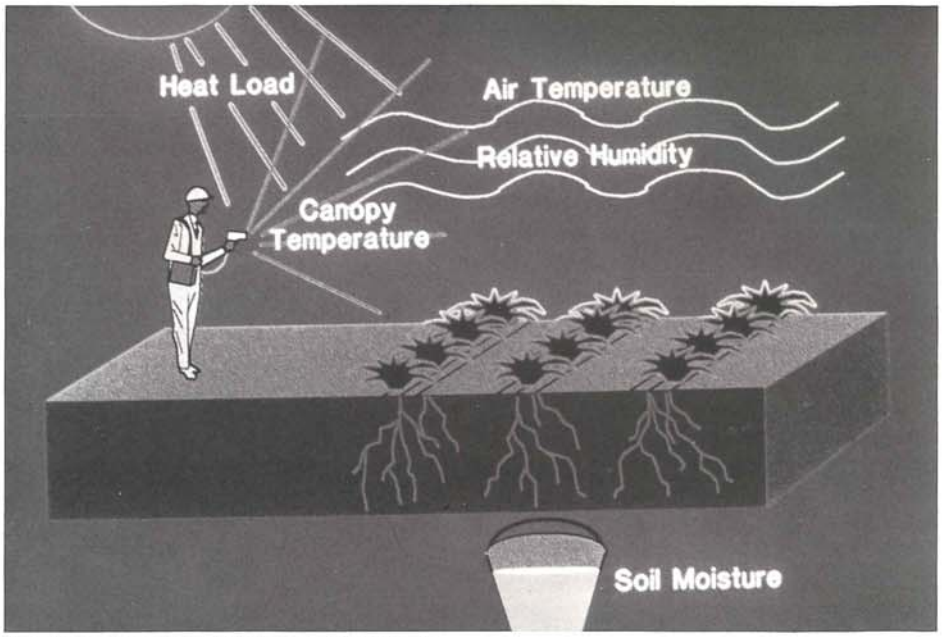
by Clinton C. Shock, Tim Stieber, Bronson Gardner, and Angela Bibby

BOISE, Idaho — **R**ecent advances in infrared thermometers are giving potato growers a new tool to evaluate water stress.

Researchers are using infrared guns that can detect hot and cool places in crop canopies as well as hot spots inside potato storages.

The following is edited from a presentation made earlier this year at the Idaho Irrigation Equipment School in Boise.

In brief, the following is based on current research into the use of infrared guns on potatoes, sugar beets and alfalfa seed. With potatoes, in particular, information collected is useful as an insurance tool to make sure all parts of the field are remaining cool. If parts of the field are heating, the producer can intervene to determine the cause. If necessary, irrigation management practices can then be corrected.



Using canopy temperatures to evaluate stress.

For producers considering using infrared guns, the following are suggestions based on our studies over the past three years:

- ***Planning observations*** — Determine a logical sequence of fields. Make measurements in logical parts of each field, including well-watered areas, areas where soil water is regularly monitored, and areas where problems may occur. Plan how data will be recorded or unloaded into a computer (optional).
- ***Prepare to take readings*** — Make sure your batteries are freshly recharged. Clean the lens. Let the gun equilibrate to the air temperature where it will be used. Otherwise the gun will read an incorrect air temperature and calculate bogus crop water stress index (CWSI) values.
- ***Field conditions*** — Proper environmental conditions help assure correct readings. Take readings near solar noon. At 1 p.m., the sun may be nearly straight overhead. If so, 12 to 2 p.m. would be the best time. Take readings only in bright sunshine. Low wind speed contributes to accurate readings. Foliage must be dry, lacking moisture from previous irrigations or rain showers.
- ***Method to make readings*** — Stand inside the field. Readings made while walking down a road or from a pickup compare crop canopy temperatures with air that is not above the crop. Hence, the information is inaccurate. Keep the sun at your back and aim the gun directly away from the sun. Otherwise canopy temperature will register too cool. Hold the gun three feet above the canopy. Consistency leads to comparable results. Aim the gun 30 feet from you into the crop. Avoid hitting soil (often too hot) or the sky (often too cold) or distant objects (many temperatures) with your aim. Aim at least two seconds before you pull the trigger. Make multiple measurements, 10 to 20 readings per location. These multiple measurements take only a few seconds and the infrared gun will average the readings automatically.

Consistent methods of preparation and field readings will lead to more valuable field observations.

Crop canopy temperature varies according to a number of factors, including plant water status, air temperature, solar intensity, relative humidity, and wind speed. For an instrument to be useful, enough variables need to be measured to establish meaningful relationships.

The integration of IR (infrared) thermometer measurements of crop canopy temperatures with air temperature and relative humidity measurements is accomplished by a tiny computer inside the IR gun.

As the air becomes drier and drier, the potential for a crop's evaporative cooling through transpiration increases. If we have a well-watered crop, it has the potential to be using water at the maximal rate. The maximum canopy cooling effect is measured as a change in temperature as a function of the scarcity of water in the atmosphere. The scarcity of water in the atmosphere is called the water vapor pressure deficit (VPD). The VPD variable takes into account relative humidity and temperature. A maximum cooling curve for sugar beets, at Ontario, Oregon, is presented in Figure 1. The vertical axis of Figure 1 is the difference between the leaf and air temperatures. If we are at zero on the curve, the air and the leaf are at the same temperature.

A graph of maximal canopy temperature can also be made. Under intense sunlight and severe water stress the stomata are closed. Maximal heating of the canopy occurs. A graph of maximal canopy heating is an upper boundary of plant canopy temperatures (Figure 1). Of course, in the field it is possible to make measurements above the maximum crop canopy temperature by shooting a field with an infrared gun and hitting hot bare soil. Such a hot spot is not part of the plant canopy.

The region between maximum canopy cooling and maximum canopy heating can be arbitrarily divided into a crop water stress index (Figure 2).

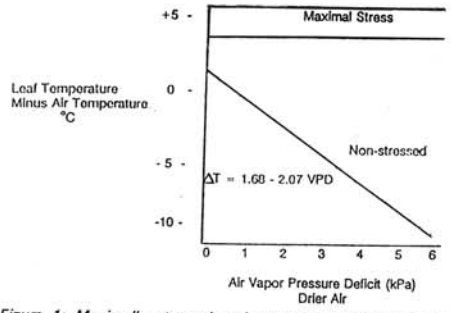


Figure 1: Maximally stressed and non-stressed baselines for canopy cooling of sugar beets Malheur Experiment Station, OSU, Ontario, Oregon, 1987 and 1988.

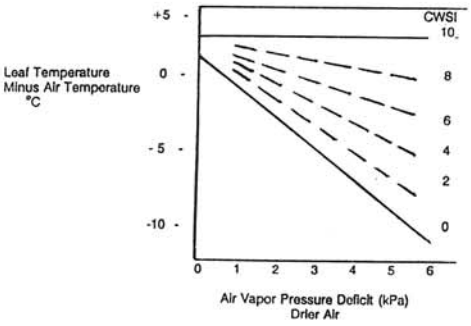


Figure 2: Crop water stress indices for sugar beets, Malheur Experiment Station, OSU, Ontario, Oregon, 1987 and 1988.

Water stress index numbers often go from 0 to 1 or from 0 to 10. For simplicity, the scale of 0 to 10 is used in this discussion. The CWSI is the extent to which the crop is failing to cool itself through evaporative cooling. When the CWSI is equal to zero, the crop is cool, and when the CWSI reading is 8, the crop is extremely hot. Visible wilting occurs with different crops between a 5 and 10 reading. For example, potatoes and sugar beets start to wilt in the middle of the CWSI range while alfalfa wilts higher, and sage brush would wilt near 10. Of course, each crop has its own baseline curves and corresponding CWSI relationship.

In our research, we used several crop examples to illustrate: potatoes, sugar beets and alfalfa seed. The three demonstrate different degrees of crop susceptibility to water stress and different uses of CWSI information generated with a Scheduler, a type of infrared gun.

Potatoes

Potatoes are very sensitive to water stress. Water stress during tuber growth leads to a rapid loss in tuber grade and internal tuber quality. Longer durations of water stress may lead to crop loss.

Although growers intend to maintain their potato fields in well-watered condition, it is sometimes difficult to check whether entire fields are well watered. Scheduled CWSI readings can readily detect if parts of a field are hotter than other parts. Hot spots are usually associated with poor soil water status or root disease. Consequently, CWSI indices may be a helpful diagnostic tool.

In trials with a range of applied water from 100 percent evapotranspiration to substantial deficiencies, crop canopy temperatures reflected soil water conditions. As CWSI values increased, crop yield declined, tuber specific gravity declined, and the average stem and fry color became darker. In addition to the declines in yield and internal quality, market grade deteriorated rapidly with increased CWSI (Figure 3). Potatoes are clearly a crop where CWSI values must be minimized. Ir-

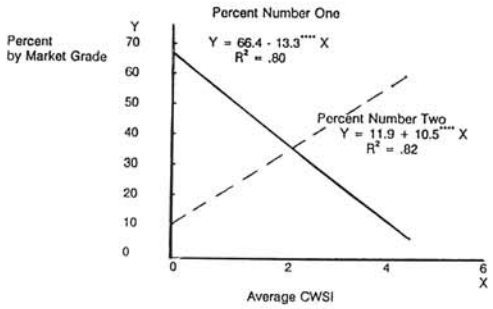


Figure 3: Relationship between Russet Burbank market grade and average crop water stress index, Malheur Experimental Station, OSU, Ontario, Oregon, 1987 and 1988.

AGRI-CHECK SOIL & TISSUE ANALYSIS PAYS!

UNIVERSITY APPROVED METHODS

AGRI CHECK

AGRI - CHECK, INC.
AGRICULTURAL TESTING LABORATORY
CROP SCIENCE CONSULTANTS

ONE DAY TURN AROUND

COURIER SERVICE TO DEALERS Yakima Valley & Columbia Basin

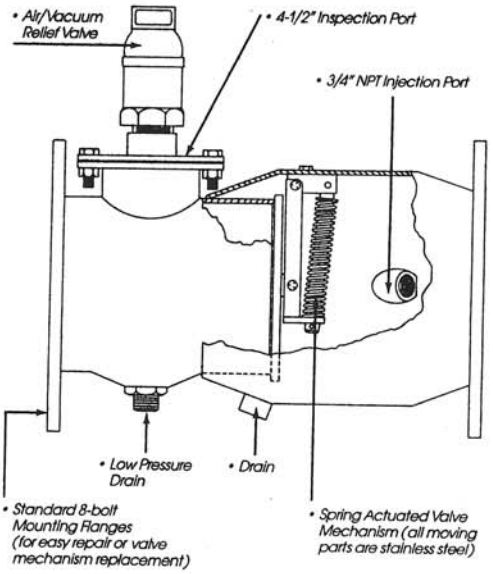
Isn't It Time You Checked Us Out?

323 6th St.,P.O. Box 705 * Umatilla, OR 97882

*(503) 922-4894 * TOLL FREE 1-800-537-1129*

IS IRRIGATION SPECIALISTS

BLU RIVR™ Check Valve


• Air/Vacuum Relief Valve
• 4-1/2" Inspection Port
• 3/4" NPT Injection Port
• Low Pressure Drain
• Drain
• Standard 8-bolt Mounting Flanges (for easy repair or valve mechanism replacement)
• Spring Actuated Valve Mechanism (all moving parts are stainless steel)

Approved for Kansas & Nebraska.

Recent legislation makes check valves mandatory equipment on irrigation systems for growers who are chemigating. The state laws are explicit about the specifications of approved check valves. Blu Rivr™ Check Valves meet or exceed all approved requirements.

Protect your well water and comply with the law with a Blu Rivr Check Valve.

If you are chemigating and your irrigation system shuts down, you could have big trouble. The "treated" water in your system is usually siphoned back into your well and can seriously affect the quality of your water source.

With a Blu Rivr Check Valve in place, you can eliminate this potential hazard. Blu Rivr Check Valves prevent water already mixed with chemicals from flowing into your well in the event of an untimely shut down.

Why take chances?

Don't run the risk of contaminating your ground water. See your nearby Blu Rivr dealer about a check valve and rest easy.

Reinke Manufacturing Co., Inc., reserves the right to discontinue models at any time, or to change specifications design or accessories without notice and without incurring obligation.

TOLL FREE IN WASH. 1-800-572-9628 PASCO, WASHINGTON (509) 547-1761

rigation must be managed to minimize stress on the crop. Even slight deviations from well-watered conditions can lead to losses of yield, grade and internal quality.

Sugar Beets

Deeper rooted than potatoes, sugar beets are an example of a crop with greater tolerance to water stress. Sugar beets are very sensitive to plant stand losses and final yield losses if stressed for water while the crop is being formed. But once the canopy has closed over the soil, beets are not nearly as sensitive to water stress.

In a field trial in 1988, sugar beets were grown under five irrigation criteria (Table 1). All treatments received five 12-hour irrigations from planting until the end of June and one 10-hour irrigation before harvest for a total of 70 hours of furrow irrigation. During the season, all irrigations were in rows compacted by wheel traffic (every other row). The well-watered check treatment was watered whenever the top two feet of soil averaged drier than -0.7 bars, resulting in an additional 100 hours of furrow irrigation during the season. Beets with irrigation criteria of CWSI = 1, CWSI = 3, and CWSI = 5 were only watered when the plant canopy in their respective plots reached CWSI = 1, 3, and 5, respectively.

Table 1. Sugar beet response to irrigation treatments, 1988, Malheur Experiment Station, OSU, Ontario, Oregon.

Treatment	Irrigation hours*	Yield t/ac	Sucrose %	Sugar lb/ac
1. Soil water -0.7 bars	170	38.1	16.6	10390
2. CWSI = 1	114	38.3	15.7	9850
3. CWSI = 3	88	37.9	15.4	9600
4. CWSI = 5	81	35.5	15.8	9300
5. CWSI = 5 only for July	146	37.9	16.6	10300
LSD(.05)		1.8	0.6	370

*Based on the hours of irrigation in wheel traffic furrows.

Irrigation requirements were 44, 18 and 11 hours above the basic 70 hours, and recoverable sugar decreased 5, 8, and 11 percent. When irrigation water conservation is needed, large savings may be possible with only moderate losses in total recoverable sugar.

During the 1987 season, a similar trial had shown no relationship between July stress and recoverable sugar. In 1988, moderating irrigations during July by watering with the CWSI = 5 and returning to a well-watered condition after July saved 14 percent of the irrigation water with no loss in recoverable sugar.

Alfalfa Seed

Alfalfa is a very deeply rooted crop that may or may not be using water from deep in the soil profile. Plant use of deep water cannot be conveniently measured using soil probes or devices.

Alfalfa seed is an example of a crop where water stress is positively associated with seed yields (Figure 4).

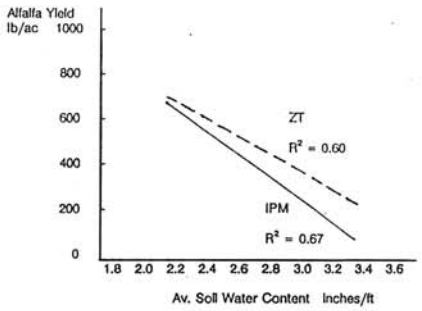


Figure 4. Relationship between the average soil water content (second foot of soil) and Wrangler alfalfa seed yields with zero tolerance and integrated pest management insect control practices. The soil water was averaged during bloom and seed fill. Malheur Experiment Station, OSU. Ontario, Oregon, 1988.

Water stress cannot be carried to the point of burning up the crop. but when CWSI values are taken on alfalfa seed, the areas with the highest CWSI values are associated with higher seed yield.

Custom Chemicals Inc.
J.W. Cox
Northwest authorized dealer for..

COM-AIR-CO
REFRIGERATION

GELLERT
VENTILATION

★ GELLERT VENTILATION SYSTEMS
★ COM—AIR—CO REFRIGERATION SYSTEMS
★ POTATO STORAGE MAINTENANCE AND REPAIR
★ SERVICE LOCATIONS IN MOSES LAKE & KENNEWICK

Sid Winzler — President

Moses Lake (509) 765-7401 | Toll Free 1-800-635-6475 | Kennewick (509) 582-8365

PROTECT YOUR INVESTMENT WITH
CROP INSURANCE
We Specialize in the Following Crops:

POTATOES
CORN
PEAS
BEANS
WHEAT
APPLES

PIA PROFESSIONAL INSURANCE AGENTS

SLOAN INSURANCE, INC.
(509) 488-9623

P.O. Box 449
Othello, WA 99344

Gregory H. Sloan CIC
Randall N. Pixton
Brad K. Risenmay

Each time the crop is watered, CWSI values fall.

Considering the association of CWSI patterns with seed yields, patterns that have prolonged low CWSI values between bud stage and seed set are associated with low yields (Figure 5). Low CWSI is associated with high vegetation growth. High CWSI patterns over time are associated with high seed yields. Of course, weeds, insect pests and pollinators must be closely managed to obtain high seed yields.

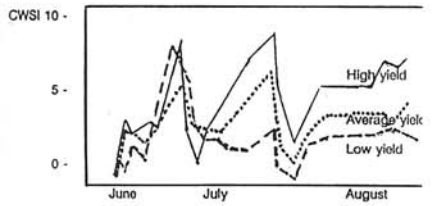


Figure 5. CWSI patterns and associated alfalfa seed yields, 1987. Malheur Experiment Station, OSU, Ontario, Oregon.

CWSI patterns suggest that irrigations should be delayed as much as possible. CWSI patterns also suggest that irrigations should be as superficial as feasible so that stress is only partially relieved. ■

MARKET:

have been about 335 million cwt., 9 percent larger than the actual 307 million cwt. Using the USDA's price-production relationship, 1988 crop potato prices would be about 36 percent lower. That means $5, instead of $8, potatoes.

Looking ahead to the 1989 crop, I expect that U.S. acreage will increase. At the Washington and Idaho potato schools, I predicted that acreage will increase about 2 to 5 percent. Others are predicting that acreage will increase 10 percent or more.

It is likely that yields will also increase. University of Idaho Economist Paul Patterson, who has studied weather patterns, says that never in the history of modern U.S. agriculture has there been two consecutive drought years like 1988 — not even during the dust-bowl years of the 1930s. If you are betting on another drought to boost potato prices, your chances are slim.

Let's look at a "what-if" example for the 1989 crop. What if acreage increases 5 percent and yields return to the 1987 level of 315 cwt.? This would mean a crop of about 350 million cwt., 14 percent bigger than the 1988 crop. Using the USDA price-production relationship, prices could be about 56 percent lower.

I am very optimistic about the potato industry in the long run, but in the short run I see the evils of overproduction looming over the 1989 horizon.

Guenthner's market tip: If U.S. May 1 storage stocks are less than 44 million cwt., Idaho open-market prices will exceed $10. ■

COLD SNAP:

researcher. Soil temperatures are warmer and there are fewer problems with wind and moisture conditions. Wind can cause havoc with the application of metham sodium products, and excess moisture in the soil, sometimes a problem in the spring, can interfere with the application of Telone II.

As the 1989 growing season gets under way, Santo advises growers concerned about nematodes to make sure they are taking adequate soil samples. These should be taken before and after treatment. If chitwoodi do show up in pretreatment samples, it would be wise to harvest as soon as possible and avoid storing the tubers, regardless of how good of control subsequent samples show.

Santo says an excellent time to sample for live nematodes is in late August. Conditions are ideal to measure just how serious the problem is. There may be cause for concern and there may not. ■

TRADE TALK:

Product Promotion (VAPP) funds that will be available to Idaho this year.

Under the programs, the USDA makes annual awards to nonprofit commodity associations and private food processors for the promotion of U.S. agricultural exports in targeted foreign markets.

Seven Idaho food processing companies — American Fine Foods, Inc., Payette; Burley Fresh Pack, Burley; Idaho Pacific Corporation, Ririe; Rosecreek Vineyards, Hagerman; J.R. Simplot Food Division, Boise; Sun Glo of Idaho, Inc., Rexburg, and Ward's Cheese, Richfield — will share in $312,000 of that funding. ■

For advertising Call (509) 248-2452

AFFELDT®

Ahead of the Market with High Efficiency Packaging Machines for the Produce Industries

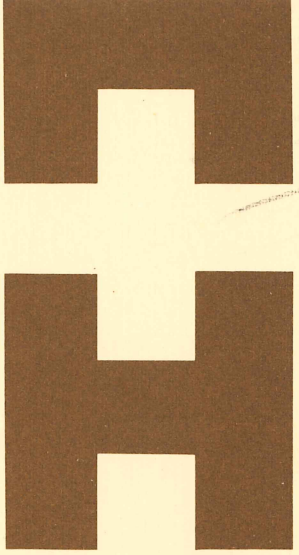
Fully computerized weigher:

- Average weight of give away less than 1% of target weight
- Underweight eliminated
- Higher performance and speed
- Can be integrated in existing packing house equipment
- Easily serviceable
- Wear resistant

Triple R Industries
Route 9W
Milton, New York 12547
(212) 246-3865
(914) 795-2161

Affeldt Inc.
Central Spareparts Depot
1470 Hillcrest Road
Norcross, Georgia 30093
(404) 921-6300

A.P.M. DISTRIBUTING INC.
APM Distributing Inc.
1470 Hillcrest Road
Norcross, Georgia 30093
(404) 921-6300



MAINE SCIENCE AND TECHNOLOGY COMMISSION

TECHNOLOGY INNOVATION PROJECT

Project Submitted by:

Central Aroostook Soil and Water Conservation District

A Project to Evaluate Plant Stress Monitoring As a Way to Manage Supplemental Irrigation

Final Report and Evaluation

February 28, 1989

R. D. Hews & Associates

TABLE OF CONTENTS

	Page
Project Description	1 - 3
Evaluation	4 - 11
Table #1 Irrometer and Scheduler Readings	6
Chart #1 Comparison Chart for Harrison Farms	7
Chart #2 Comparison Chart for Lagerstrom Farms	8
Table #2 Average Yield Differences	9
Summary and Conclusions	12 - 13
Literature Cited	14
Appendix I	15

Project Description

In October of 1987 the Central Aroostook Soil and Water Conservation District along with Lagerstrom Farms, Harrison Farms, and R. D. Hews & Associates, all of Presque Isle, submitted a proposal to the Maine Science and Technology Board for a Technology Innovation Project Grant. The project would conduct a feasibility study of using a plant stress monitor to manage the application of supplemental water by irrigation on potatoes in Northern Maine. A plant stress monitor known as Scheduler was to be obtained from Standard Oil Engineered Material Division and used to monitor plant stress during the summer and early fall of 1988.

Potato production variability in Northern Maine is a function of water supply. In Maine it has been shown that a highly significant negative correlation exists between plants suffering water stress and potato yields (11). In a study conducted in Maine (1), researchers reviewed climatic data and run off records for a thirty year period and postulated that "even in the wettest years, potato production could have possibly been helped by properly timed supplemental irrigation." Available natural moisture, available between May 15 and September 5, is estimated to be 8.88 inches for Aroostook County; while the normal consumptive use for potatoes for the same period is 14.96 inches (10). Analysis of rain fall patterns over a growing season is potentially misleading and while an analysis of monthly precipitation figures may appear better, the fact remains that a large portion of a month's rain fall can occur in one storm (2). If large storms occur at the beginning and end of consecutive months it is possible to have periods of time during the

month of extremely dry soil conditions. Several studies relating to potato yield response to supplemental applied water have been conducted in Maine (2, 3, 9) and two studies have been conducted relating the proportion of US #1 grade potatoes to supplemental applied water (2, 8). While many of these studies pertaining to yield response are several years old, a recent study (7) indicates that the potential exists for increase return from improved quality and yields through irrigation.

In order to maximize the potential that supplemental irrigation can have, irrigation scheduling must be oriented toward maximum profit per unit of applied irrigation water. In this area there is no published data in Maine and scheduling techniques are currently being developed. It is hoped that the use of a plant stress monitor as outlined in the district's proposal would improve irrigation scheduling techniques.

In other parts of the country traditional methods of scheduling have been based upon a fixed level water deficit throughout the season (4). Computer based techniques for scheduling, based upon an estimated water balance have met with some success in semi-arid areas (7, 6). Periods of water stress can also be determined through the use of remotely sensed cropped canopy temperatures (5). Irrigation scheduling in Maine currently replies upon monitoring soil moisture tension with the use of instruments known as tensiometers. There have been recent efforts to develop a potato irrigation scheduling program using these instruments (2). An experiment conducted in 1986 at the University of Oregon's Malhur experiment station by Dr. Clintant Stock, indicated that closely monitored plant stress can result in increased yields of US #1 potatoes by using less water than would normally be used.

The goals and objectives proposed by the District were to obtain a plant stress monitor and evaluate it's effectiveness to schedule supplemental irrigation in Northern Maine. It was hypothesized that monitoring a plant stress and applying supplemental water by irrigation based upon the level of plant stress would improve the yield and quality of potatoes under irrigation verses those that were not irrigated. It was also anticipated that monitoring plant stress would result in an improved method of managing supplemental irrigation.

Evaluation

On the two participating farms, approximately 30 tensiometers were set out in irrigated and nonirrigated areas to measure soil moisture content. These tensiometers were set out by the district's technician under the supervision of researchers from the University of Maine at Orono. In addition to the tensiometers, several gypsum soil moisture blocks were also installed on the two farms. On at least 18 different occasions, the scheduler plant stress monitor was used to determine the plant stress index at several locations (both irrigated and nonirrigated) on each of the two farms (refer to Appendix I). The farm managers were prepared to operate a portion of the irrigation equipment based upon recommendations made by the plant stress monitor and to operate the remainder of the irrigation equipment based upon readings from the tensiometers. Separate sampling techniques would be used to determine any yield or quality difference between the two management techniques. In the fall of 1988, the district's technician took numerous samples from both irrigated and nonirrigated plots to determine differences in yield and quality. These samples were analyzed by researches at the University of Maine at Orono (refer to Table 2).

It was assumed that the monitoring of plant stress would result in earlier detection of when supplemental irrigation would be required and would be an improved technique over the use of tensiometers. Based upon the results and samples taken during the 1988 growing season this does not appear to be the case. From Table 1 and Charts 1 and 2 we find that plant stress readings using the Scheduler and soil moisture readings using tensiometers appear to move together. In fact at no time during the course of the summer and early

fall was there a different recommendation regarding when to irrigate by using either of the two methods. Therefore there was no yield or quality differences attributable to the technique used to manage supplemental irrigation.

Irrigation does appear to be beneficial based upon the data contained in Table 2. Yield differences at a statistically significate level were obtained for several of the potato varieties studied. Increased yields of as much as 151.36 cwt/acres were realized. Fixed and variable costs associated with the operation of the irrigation systems is estimated to be $108.06 per acre (7). Using the 1987-88 season average price of $4.25 per cwt for Maine Potatoes, a 151.36 cwt per acre yield increase would result in a net of $535.22 per acre in additional revenues. This obviously is a significant economic benefit to those farms that irrigate (net per acre in additional revenues ranged from $5.67 to $535.22 excluding Belrus which showed no response to irrigation in 1988). Average yield increase for all varieties was 69.9 cwts per acre which created $297.08 in additional revenues and $189.92 in additional net revenues ($297.08/ac gross less $108.96/ac fixed and variable cost) using the 1987-88 season average price for potatoes.

TABLE 1
1988 IRRIGATION PROJECT
AVERAGE READINGS

ARRISON FARMS

ATE	IRROMETER READING (centibars)	SCHEDULAR READING (stress index)
7/06/88	54.2	1.6
7/08/88	45.8	2.0
7/11/88	11.2	0.0
7/13/88	9.5	1.4
7/15/88	20.2	-0.9
7/18/88	16.9	0.4
7/20/88	11.4	-0.2
7/25/88	63.3	-0.2
7/29/88	44.7	1.1
8/01/88	63.3	1.9
8/12/88	30.7	0.6
8/18/88	9.0	-0.3
8/24/88	4.1	0.4
8/29/88	5.3	1.4
9/02/88	0.9	0.1
9/07/88	1.9	-0.1

AGERSTROM FARMS

ATE	IRROMETER READING (centibars)	SCHEDULAR READING (stress index)
7/06/88	1.6	0.2
7/08/88	8.9	0.5
7/11/88	15.5	0.9
7/13/88	12.1	1.3
7/15/88	20.5	1.2
7/25/88	14.4	0.2
7/29/88	13.3	0.5
8/01/88	29.5	0.9
8/12/88	27.1	0.3
8/17/88	6.5	-0.3
8/22/88	16.5	1.5
8/24/88	24.9	2.2
9/02/88	11.7	-0.3
9/07/88	8.5	0.4

Chart #1

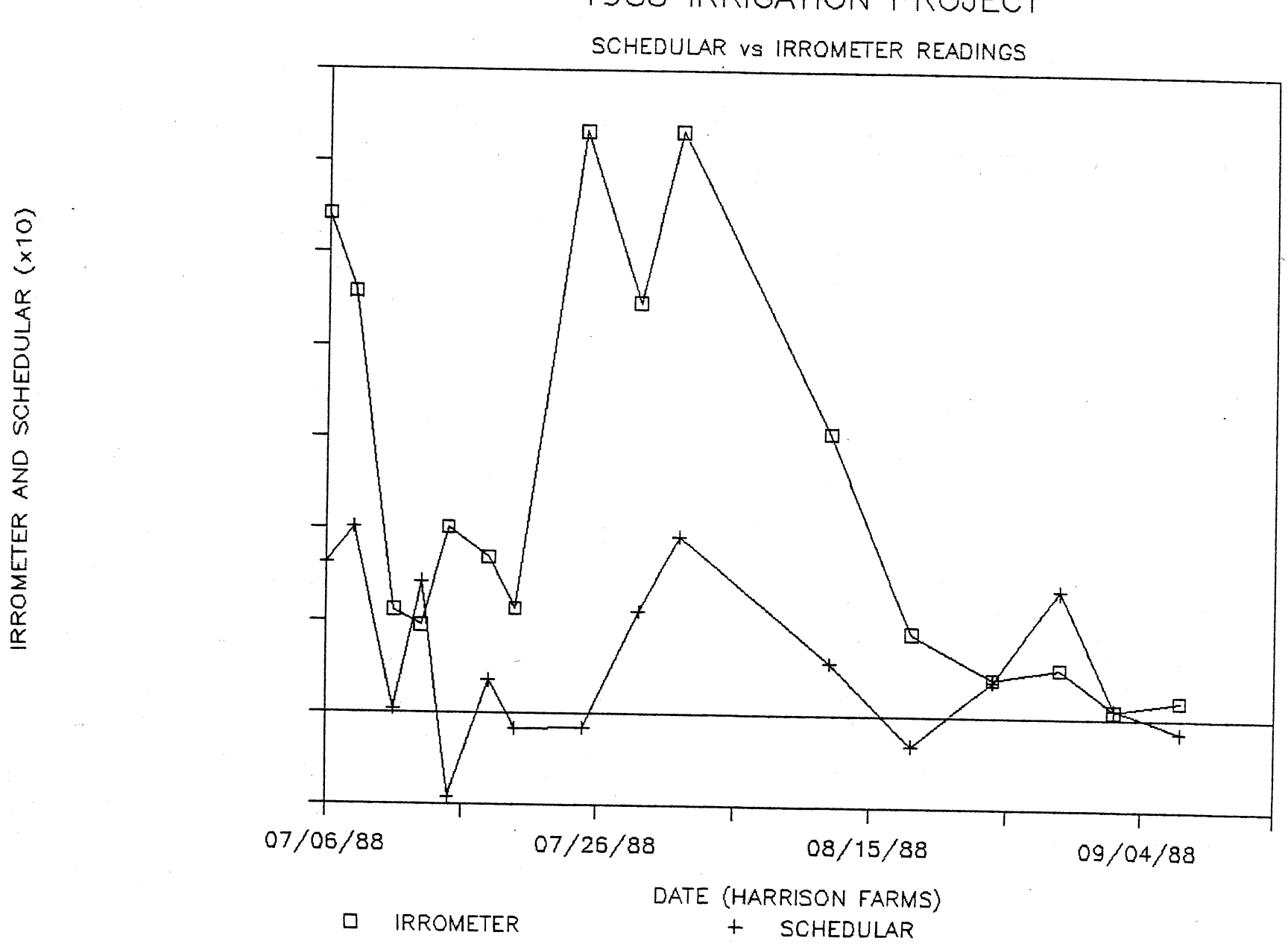

1988 IRRIGATION PROJECT
SCHEDULAR vs IRROMETER READINGS
IRROMETER AND SCHEDULAR (x10)
07/06/88
07/26/88
08/15/88
09/04/88
DATE (HARRISON FARMS)
IRROMETER
SCHEDULAR

Chart #2

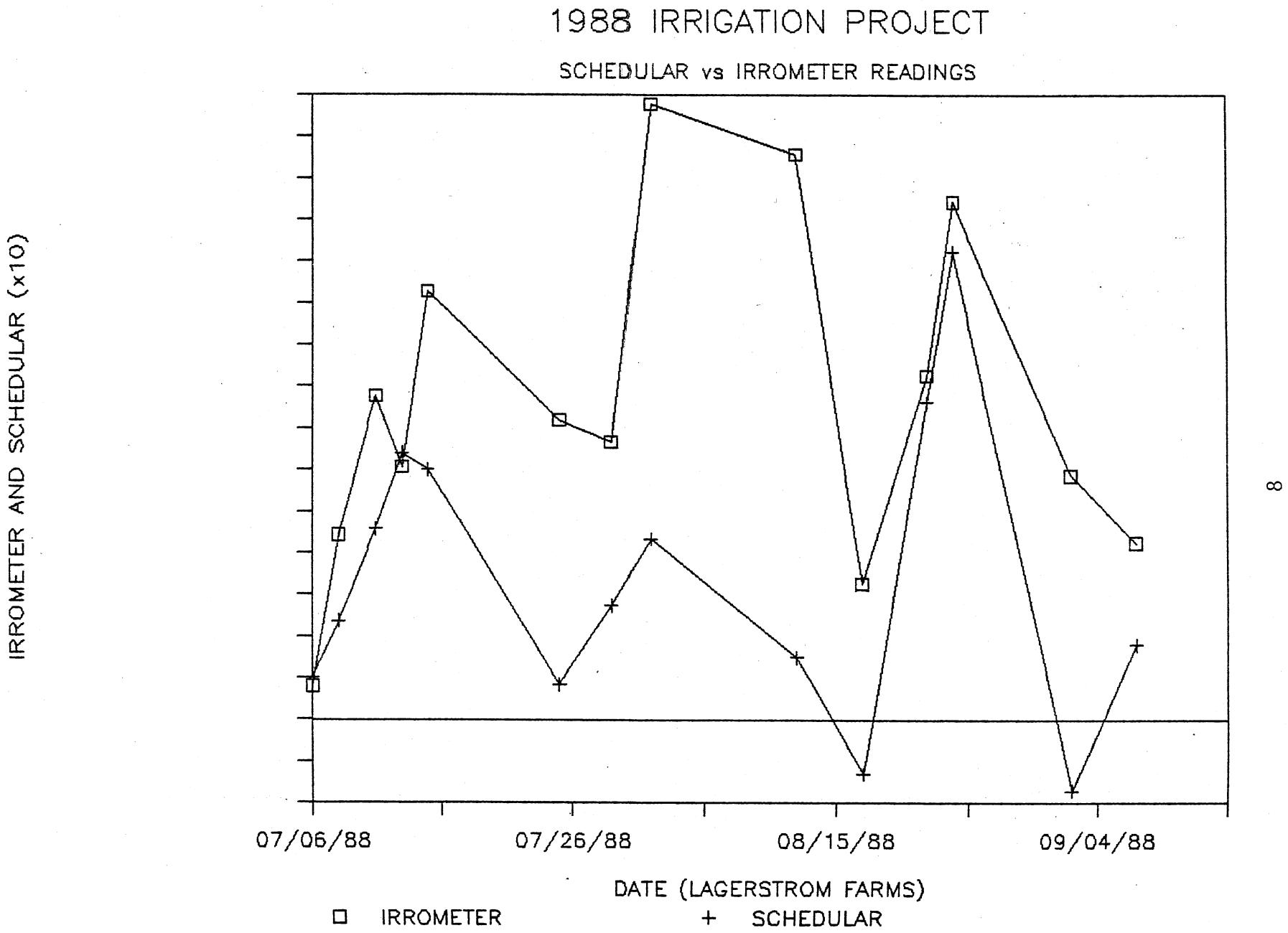

1988 IRRIGATION PROJECT
SCHEDULAR vs IRROMETER READINGS
IRROMETER AND SCHEDULAR (x10)
07/06/88
07/26/88
08/15/88
09/04/88
DATE (LAGERSTROM FARMS)
IRROMETER
SCHEDULAR

Table 2. Average Yield Differences Due to Irrigation by Variety and Farm for 1988

Variety	Farm 2	Farm 3
	cwt./ac.	
Superior	26.72[N.S.a]	120.01***
Belchip	90.44**	--[b]
Katahdin	33.84[N.S.]	--
Norchip	51.47**	--
Russett Burbank	--	151.36***
Belrus	--	-4.48[N.S.]
Kennebec	89.90***	--

[a] Some samples marked "not-irrigated" may have received some irrigation from a hand-move system.

[b] Variety not grown on farm in 1988.

** (***) Statistically significant at the 5% (1%) level.

N.S. No statistically significant difference was found in the samples taken.

During a meeting of participating farmers and the district's staff, an evaluation was conducted as to whether or not the plant stress monitoring was an improved method of managing irrigation. The consensus of opinions was that it is probably not. Several reasons were uncovered during this meeting.

In order to effectively monitor plant stress there needs to at least an 18 inch plant canopy before the plant stress monitor will properly work. If it "sees" to much bare ground it will generate distorted plant stress readings. Therefore, it is difficult to use plant stress monitoring for determining when to apply supplemental irrigation during the early stages of the growing season. During this period of time it appears best to use soil moisture monitoring techniques such as a tensiometer in order to determine when to apply supplemental water.

Another difficulty discover with the use of the plant stress monitor was that it required 65% or greater light intensity. Cloudy weather of any kind will distort the plant stress readings generated by the plant stress monitor. During the summer of 1988, by the time the plant canopy was of sufficient size to obtain accurate plant stress readings, we entered a period of time which many of the days were cloudy or partly cloudy making it difficult to obtain accurate plant stress readings.

Between the time of sufficient plant canopy and prior the time when the plants start to die the plant stress monitor readings were very similar to readings obtained by the tensiometer (refer to Charts 1 and 2). It was also noted the when the ground was heavily saturated with water (i.e. after a heavy rain or heavy irrigation) the plant stress monitor showed the plants to be under stress in the same fashion it would if the plant were under stress due to lack of water.

The conclusion reached by the district's technician was that in an arid climate it appears that the plant stress monitor could be effectively used to conserve water while maintaining improved quality and yield. Based upon the conditions that existed during the summer and early fall of 1988 it was not consistently reliable in its readings of plant stress.

When conditions are ideal the plant stress monitor is a reliable method in which to manage and schedule the application of supplemental water to potatoes. Readings can be obtained faster than using tensiometer in terms of the time needed to take readings. Also tensiometers require more maintenance time and installation time than is required with the plant stress monitor.

Summary and Conclusions

In summary, the participating farmers and District staff concluded that the timeliness of data collection by the district's technician, degree to which cooperating farmers participated and provided assistance in management of irrigation systems, and the methodology used to sample for yield and quality difference were all satisfactory met. The District technician was assisted by researchers from the University of Maine at Orono during the installation of monitoring equipment and the use of the plant stress monitor. He was also assisted by University of Maine at Orono researchers during the sample collection process during the fall. The two cooperating farmers participated fully and provided all necessary assistance during the management of the irrigation systems in conjunction with recommendations made by the district's technician. The methodology used for sampling was developed by researchers at the University of Maine at Orono and have been used for four consecutive years.

While statistically significate yield and quality improvements were obtained by supplemental irrigation during the 1988 growing season, there were no differences in the recommendations of when to irrigate when comparing the use of the plant stress monitor with tensiometers and therefore, there was no yield or quality differences attributable to the use of one management technique over the other. Therefore the economic benefit achieved by the technology transfer project is concluded to be none. Clearly there was economic benefit derived through the use of supplemental irrigation for most varieties included in the sampling, and this economic benefit in many cases exceeded several hundred dollars per acre. The primary focus of this study

was to evaluate the use of plant stress monitoring to manage the timing of application of supplemental water and it was this part of the original hypothesis that could not be supported. The participating farmers and District staff did recommend that the District continue to work with Standard Oil Engineered Materials Division and the University of Maine at Orono researchers during the 1989 growing season whether or not there are alternative techniques which could use the plant stress monitor to aid farmers with the management of supplemental irrigation. The District also intends to look into the possibility of alternative uses for the plant stress monitor that would provide economic benefits to area farmers.

Literature Cited

1. Benoit, G.R. and W.J. Grant. 1980. Plant water deficit effects on Aroostook County Potato yields over 30 years. Am Potato J57:585-594.

2. Bourgoin, TL. 1984. Developing a potato irrigation scheduling program: The Maine situation. Am Potato J 61:195-203.

3. Gotz, S.M. 1980. Evapotranspiration from negative surfaces in Maine. Maine Life Sci Agric Exp Stn Tech Bull 97.

4. Hiler, E.A., and T.A. Howell. 1983. Irrigation options to avoid critical stress: an overview. In: H.M. Taylor et al. (ed.) Limitations to efficient water use in crop production. Am. Soc. of Agron., Madison, WI, pp. 479-497.

5. Jackson, R.D., S.B. Idso, R.J. Rginato, and P.J. Pinter, Jr. 1981. Canopy temperature as a crop water stress indicator. Water Resour. Res. 17(4): 1133-1138.

6. Jensen, M.S., D.C.N. Robb, and C.E. Franzoy. 1970. Scheduling irrigations using climate-crop-soil data. J.. Irrig. Drain. Div. Am. Soc. Civ. Eng. 96(IRI): 25-38.

7. Marra, M.C., A.S. Kezis, S.M. Goltz, W.E. Hedstrom, R. D. Hews. 1987. The economic implications of potato response to irrigation: results from 1985 field tests in Maine. Am Potato J 64:249-260.

8. Murphy, H. J., Goven and H. Plate. 1975. Effect of differential fertilizer rates and supplemental irrigation on yield, quality and chemical composition of Katahdin potatoes in Maine. Maine Agric Exp Stn Bull 714.

9. Pullen, W.E. and William E. Schrumpf. 1962. The economics of irrigation potatoes in Maine 1956-1959. Maine Agric Exp Stn Bull 604.

10. U.S. Corps for Engineers, New England Division. 1979. Feasibility report for cropland irrigation and conservation: Research/ demonstration program. Waltham, MA.

11. Van Loon, C.D. 1981. The effect of water stress on potato growth, development, and yield. Am Potato J 58:51-69.

APPENDIX I

SAMPLE OF DATA COLLECTED

by the Scheduler

Plant Stress Monitor

FIELD DATA

FLD	CROP NAME/STAGE	DATE	TIME	------AVERAGES------ CROP	AIR	RH	SUN	STRESS INDEX	VPD	CROP Std	SAMPLES TAKEN
1	POTATOES	08/04/88	15:41	+088.8	+087.2	64	032	+02.5	+1.55	+02.01	015
2	POTATOES	08/04/88	15:42	+085.3	+087.3	62	026	+00.0	+1.68	+00.01	015
3	POTATOES	08/04/88	15:47	+086.7	+086.9	66	031	+00.8	+1.47	+00.05	016
5	POTATOES	08/04/88	15:50	+084.4	+087.4	63	020	-00.9	+1.62	+00.17	015
5	POTATOES	08/04/88	15:51	+084.2	+087.2	62	015	-00.7	+1.66	+00.10	016
7	POTATOES	08/04/88	15:55	+082.6	+085.8	66	016	-01.8	+1.41	+00.08	013
3	POTATOES	08/04/88	15:56	+083.1	+086.3	64	016	-01.4	+1.52	+00.77	014
9	POTATOES	08/04/88	15:59	+083.3	+086.2	64	014	-01.1	+1.50	+00.41	014
2	POTATOES	07/26/88	14:23	+079.1	+076.5	61	085	+02.6	+1.20	+01.20	017
2	POTATOES	07/26/88	14:23	+079.1	+076.5	61	085	+02.6	+1.20	+01.20	017
3	POTATOES	07/26/88	14:20	+076.0	+075.9	60	094	+00.3	+1.22	+00.34	011
3	POTATOES	07/26/88	14:20	+076.0	+075.9	60	094	+00.3	+1.22	+00.34	011
5	POTATOES	08/04/88	16:38	+087.7	+085.7	58	000	+03.2	+1.74	+00.39	019
5	POTATOES	07/15/88	10:08	+066.3	+065.2	58	086	+00.6	+0.88	+01.13	059
5	POTATOES	07/15/88	11:35	+068.1	+067.3	50	076	+00.8	+1.12	+00.68	029
1	POTATOES	07/15/88	11:19	+066.3	+066.8	53	095	-00.7	+1.05	+00.89	053

FIELD DATA

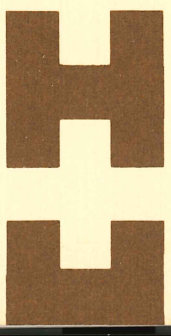
LD	CROP NAME/STAGE	DATE	TIME	AVERAGES CROP	AIR	RH	SUN	STRESS INDEX	VPD	CROP SAMPLES Std	TAKEN
1	POTATOES	07/11/88	13:03	+083.6	+086.4	57	083	-00.1	+1.82	+00.28	024
1	POTATOES	07/15/88	14:36	+071.0	+072.3	42	092	+00.2	+1.54	+02.17	041
1	POTATOES	07/26/88	14:44	+074.3	+077.6	58	072	-02.1	+1.34	+01.02	010
1	POTATOES	08/24/88	13:36	+067.4	+067.7	38	021	+00.7	+1.42	00.00	001
2	POTATOES	07/11/88	12:49	+080.2	+084.5	59	060	-02.0	+1.63	+00.50	041
2	POTATOES	07/15/88	14:49	+070.3	+072.2	43	090	-00.3	+1.53	+01.56	033
2	POTATOES	07/26/88	14:48	+076.6	+076.9	60	093	+00.1	+1.25	+01.45	027
2	POTATOES	08/18/88	13:40	+066.8	+067.2	45	094	+00.0	+1.24	+01.47	024
3	POTATOES	07/08/88	09:36	+083.5	+081.1	72	092	+01.8	+0.99	+00.89	022
3	POTATOES	07/18/88	14:05	+078.9	+080.1	56	099	+00.2	+1.54	+03.27	029
3	POTATOES	07/26/88	13:26	+075.4	+073.4	71	097	+01.5	+0.81	+00.55	018
3	POTATOES	08/30/88	12:45	+072.2	+068.9	56	092	+02.9	+1.05	+01.15	022
4	POTATOES	07/08/88	09:46	+085.1	+078.7	74	085	+05.7	+0.85	+00.98	019
4	POTATOES	07/18/88	13:50	+080.8	+079.8	56	096	+01.9	+1.50	+01.09	047
4	POTATOES	07/26/88	13:21	+074.2	+074.8	63	094	-00.6	+1.07	+00.70	015
4	POTATOES	08/30/88	12:36	+075.4	+070.9	58	092	+04.1	+1.08	+02.15	026
5	POTATOES	07/05/88	14:26	+084.6	+087.2	38	075	+01.9	+2.72	+00.44	021
5	POTATOES	07/15/88	13:23	+069.2	+071.0	51	099	-01.1	+1.25	+00.89	028
5	POTATOES	07/26/88	13:17	+076.5	+074.5	64	096	+01.6	+1.02	+01.74	010
5	POTATOES	08/30/88	12:31	+071.4	+070.7	51	078	+01.0	+1.23	+01.18	022
6	POTATOES	07/11/88	12:15	+084.5	+082.3	60	073	+02.8	+1.48	+01.11	032
6	POTATOES	07/15/88	13:12	+066.4	+073.0	44	091	-04.1	+1.54	+01.00	008
6	POTATOES	07/26/88	13:10	+075.8	+075.0	68	098	+00.4	+0.92	+00.77	026
6	POTATOES	08/30/88	12:27	+072.5	+070.8	51	092	+01.9	+1.26	+01.06	023
7	POTATOES	07/05/88	13:45	+083.0	+087.5	36	088	+00.9	+2.81	+00.55	028
7	POTATOES	07/18/88	14:14	+078.7	+082.4	50	100	-00.7	+1.85	+00.16	015
7	POTATOES	07/26/88	13:46	+073.5	+073.4	64	093	-00.2	+1.00	+00.62	019
7	POTATOES	08/30/88	12:53	+076.0	+071.5	52	099	+04.4	+1.23	+01.63	018
8	POTATOES	07/05/88	13:47	+085.7	+087.0	36	086	+02.7	+2.76	+00.26	034
8	POTATOES	07/18/88	14:18	+082.5	+083.6	47	094	+01.5	+2.07	+02.59	055
8	POTATOES	07/26/88	13:49	+074.8	+073.5	68	087	+00.8	+0.89	+00.84	021
8	POTATOES	08/30/88	12:54	+074.6	+071.2	53	080	+03.3	+1.20	+00.80	003
9	POTATOES	07/26/88	13:59	+074.3	+074.3	65	092	-00.3	+1.01	+00.89	019
9	POTATOES	08/18/88	13:10	+058.9	+061.0	50	092	-02.3	+0.90	+00.66	011
0	POTATOES	07/11/88	13:16	+083.6	+086.7	58	078	-00.4	+1.80	+00.39	025
0	POTATOES	07/15/88	13:34	+069.6	+071.8	46	099	-00.8	+1.43	+00.89	016
0	POTATOES	07/26/88	13:31	+071.9	+074.1	68	095	-02.5	+0.92	+00.48	006
0	POTATOES	08/30/88	12:47	+074.4	+071.0	52	090	+03.4	+1.23	+00.52	018
1	POTATOES	07/15/88	14:00	+069.5	+072.7	43	100	-01.3	+1.55	+00.25	009
1	POTATOES	07/26/88	14:11	+073.5	+076.8	56	072	-02.0	+1.35	+00.71	024
1	POTATOES	08/24/88	13:04	+074.0	+073.0	38	088	+02.3	+1.69	+01.87	016
2	POTATOES	07/05/88	13:57	+088.1	+089.7	31	077	+03.2	+3.26	+00.57	040
2	POTATOES	07/18/88	14:27	+080.1	+085.4	38	090	-00.1	+2.55	+00.91	017
2	POTATOES	07/26/88	14:17	+075.6	+076.4	58	087	-00.1	+1.29	+00.21	009
2	POTATOES	08/24/88	13:13	+073.6	+070.8	49	095	+03.0	+1.30	+02.01	008
3	POTATOES	07/07/88	10:32	+080.3	+076.6	65	083	+03.3	+1.09	+01.92	036
3	POTATOES	07/18/88	14:29	+081.4	+083.7	40	100	+01.3	+2.34	+00.57	026
3	POTATOES	09/07/88	13:26	+061.4	+063.1	34	089	-00.9	+1.28	+01.92	036
4	POTATOES	07/05/88	14:10	+086.4	+088.8	31	051	+02.7	+3.20	+05.18	021
4	POTATOES	07/15/88	14:16	+075.9	+073.9	42	100	+03.0	+1.63	+00.68	011
4	POTATOES	07/26/88	14:28	+078.0	+077.8	57	090	+00.9	+1.36	+01.15	021

FIELD DATA

FLD	CROP NAME/STAGE	DATE	TIME	------AVERAGES------ CROP	AIR	RH	SUN	STRESS INDEX	VPD	CROP Std	SAMPLES TAKEN
4	POTATOES	08/24/88	13:24	+072.4	+069.2	47	100	+03.3	+1.27	+00.79	015
5	POTATOES	07/07/88	10:24	+079.9	+078.5	61	080	+01.7	+1.27	+02.14	035
5	POTATOES	07/18/88	14:35	+083.3	+085.4	44	090	+01.3	+2.29	+00.62	037
5	POTATOES	07/26/88	14:32	+076.1	+076.8	56	083	+00.2	+1.37	+00.66	021
5	POTATOES	09/07/88	13:33	+058.4	+060.3	32	092	-01.3	+1.21	+00.61	035
7	POTATOES	09/07/88	13:30	+062.0	+063.5	31	093	-00.4	+1.37	+01.16	029
8	POTATOES	08/30/88	13:00	+084.5	+072.3	47	100	+11.1	+1.41	+00.68	008

FIELD DATA

FIELD	CROP NAME/STAGE	DATE	TIME	AVERAGES CROP	AIR	RH	SUN	STRESS INDEX	VPD	CROP Std	SAMPLES TAKEN
201	POTATOES	07/12/88	11:06	+082.6	+076.7	70	082	+05.2	+0.93	+01.51	026
201	POTATOES	07/26/88	11:14	+074.4	+073.8	71	094	+00.1	+0.80	+00.52	014
201	POTATOES	09/08/88	12:20	+075.9	+071.9	43	087	+04.5	+1.50	+01.25	045
202	POTATOES	07/12/88	11:09	+082.9	+078.2	67	097	+04.3	+1.07	+00.53	009
202	POTATOES	07/26/88	11:18	+071.4	+070.8	76	095	+00.2	+0.59	+01.06	011
202	POTATOES	09/02/88	13:51	+074.5	+079.3	49	085	-02.0	+1.72	+00.68	022
203	POTATOES	07/08/88	10:33	+086.7	+082.7	67	095	+03.9	+1.22	+00.91	050
203	POTATOES	07/15/88	11:24	+067.7	+066.0	53	098	+01.3	+1.01	+00.44	033
203	POTATOES	08/23/88	12:50	+076.2	+067.7	47	099	+07.8	+1.20	+01.96	026
204	POTATOES	07/08/88	10:43	+084.9	+082.0	63	092	+03.2	+1.36	+00.77	029
204	POTATOES	07/15/88	11:43	+067.9	+066.3	53	098	+01.2	+1.03	+00.44	031
204	POTATOES	07/26/88	11:01	+072.4	+071.9	73	076	+00.2	+0.71	+00.64	007
204	POTATOES	09/02/88	14:00	+076.4	+078.0	51	080	+00.1	+1.60	+01.13	033
205	POTATOES	07/08/88	10:39	+085.7	+084.3	63	067	+02.2	+1.45	+03.52	038
205	POTATOES	07/15/88	11:37	+068.7	+066.6	50	096	+01.8	+1.09	+00.46	016
205	POTATOES	07/26/88	11:32	+074.4	+072.6	70	075	+01.3	+0.80	+00.71	009
205	POTATOES	09/02/88	13:59	+077.4	+078.5	49	093	+00.7	+1.66	+00.59	021
206	POTATOES	07/15/88	11:55	+069.0	+067.1	51	088	+01.6	+1.11	+01.54	044
206	POTATOES	07/26/88	11:47	+074.1	+072.3	72	096	+01.4	+0.73	+01.06	016
206	POTATOES	09/08/88	12:42	+069.2	+072.6	42	085	-01.4	+1.56	+01.18	056
207	POTATOES	07/20/88	10:46	+065.5	+066.5	72	047	-01.3	+0.60	+00.62	013
207	POTATOES	07/26/88	10:52	+075.2	+075.8	59	097	-00.0	+1.24	00.00	001
207	POTATOES	09/08/88	12:37	+069.6	+072.7	40	080	-00.9	+1.64	+01.24	042
208	POTATOES	07/26/88	11:54	+071.5	+071.9	70	100	-00.7	+0.78	+00.25	015
208	POTATOES	08/18/88	14:35	+065.9	+064.9	44	099	+01.0	+1.15	+01.27	021
209	POTATOES	07/15/88	12:07	+073.2	+070.9	48	090	+02.6	+1.34	+01.06	005
209	POTATOES	09/08/88	12:29	+075.4	+073.9	37	084	+02.9	+1.77	+01.58	057
210	POTATOES	08/18/88	14:24	+065.6	+065.7	46	084	+00.0	+1.15	+01.36	017
211	POTATOES	08/18/88	14:28	+064.9	+064.1	46	088	+00.6	+1.10	+01.45	027
213	POTATOES	07/12/88	11:17	+082.9	+078.3	66	092	+04.2	+1.11	+00.97	024
215	POTATOES	07/26/88	11:37	+072.4	+072.7	71	069	-00.5	+0.78	+03.11	014
215	POTATOES	07/26/88	11:37	+072.4	+072.7	71	069	-00.5	+0.78	+03.11	014
224	POTATOES	08/23/88	11:31	+068.8	+062.5	52	095	+05.6	+0.91	+00.98	019
225	POTATOES	07/26/88	11:38	+075.0	+071.9	66	100	+02.6	+0.88	+00.89	004
225	POTATOES	07/26/88	11:38	+075.0	+071.9	66	100	+02.6	+0.88	+00.89	004



R. D. Hews & Associates
P.O. Box 1788
Presque Isle, Maine 04769
207-764-0300
Telex 853020
Management Plus for AgriBusiness